Less is More: Simplifying Inventory Tactics

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ABSTRACT

Millions of small and medium-sized enterprises (SMEs) fail every year in the United States, and in many instances the root cause of failure is more often due to operational inefficiencies than external factors. One way SMEs can overcome operational inefficiencies is by implementing inventory management strategies, such as modularization and postponement, to increase profitability, production efficiency, and forecast accuracy. The sponsoring company for this project is a small consumer packaged goods (CPG) company that recently implemented a modularization and postponement strategy to its main product. We quantified the impact of the new strategy by measuring six key performance indicators (KPIs) before and after implementation through statistical analysis and Monte Carlo simulation analysis. Our analysis found that the new strategy increased profitability by 14.57%, increased production efficiency by 50%, decreased MAPE by 42.2% and increased warehouse capacity by 52.6%. Modularization and postponement can be successfully implemented in SMEs, and these strategies increase profitability and reduce operational inefficiencies.

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1. **INTRODUCTION**

There are around 30 million small and medium-sized businesses (SMEs) in the United States as of 2022 (USTR, 2022). About 20% of SMEs fail within the first year, and 50% of SMEs fail by their fifth year (SBA.gov, 2012). One study concluded that the root cause of failure for SMEs was due to internal shortcomings more often than external macroeconomic factors such as interest rate fluctuations and Gross Domestic Product contractions (Gonzalez, 2017). Three examples of internal shortcomings that can cause SMEs to fail are scaling too quickly, operating inefficiently, and misaligning strategy and execution (Goltz, 2011). As SMEs seek to overcome internal shortcomings, they must develop operational solutions strategically and cost-effectively to resolve inefficiencies.

Effective supply chain management strategies can help companies of all sizes avoid pitfalls that lead to failure. Our research aims to quantify the impact of two inventory management strategies, modularization and postponement, in a small business setting at a company that specializes in selling one product.

The sponsoring company for this capstone project is an SME that has experienced rapid growth over the past two years. The company specializes in selling one product that is sold in five different configurations that differ by weight. The rapid growth exposed operational inefficiencies in its demand planning, production, procurement, and warehousing operations because each of the five configurations used different components and production processes. In September of 2021, the sponsoring company implemented a modularization and postponement strategy to its main product in an attempt to improve its operational inefficiencies.

Modularization and postponement are two inventory management strategies that can help companies, such as the sponsoring company, improve on operational inefficiencies. Modularization can be defined as using interchangeable components in groups of products, which decreases the number of components required for assembly and decreases production complexity. Postponement can be defined as delaying a product's final assembly until an order is placed, which decreases inventory obsolescence and improves forecast variance. When modularization and postponement are implemented simultaneously, it helps businesses, especially SMEs, increase efficiency and reduce complexity throughout the supply chain.

The KPIs that were used to quantify the impact of the new strategy were mean absolute percentage error (MAPE), total spend, production efficiency, order fulfillment efficiency, warehouse capacity, and profitability. Statistical analysis and Monte Carlo simulation analysis were used to identify the main drivers of revenue and profitability, and test how those drivers affected profitability under different scenarios. Our results show that the new strategy decreased MAPE by 42.2%, increased production efficiency by 50%, decreased order fulfillment efficiency by 65%, increased warehouse capacity by 52.60%, and increased profitability by 14.57%. Subsequent sections will review the motivation, problem statement, literature review, sponsoring company overview, data and methodology, results and analysis, discussion and recommendations, and conclusions.

1.1 Motivation

Implementing the new inventory strategy produced immediate benefits for the sponsoring company. Manufacturing capacity increased by 50% and inventory obsolescence was nearly zero. However, order fulfillment times increased after implementing the new strategy and the sponsoring was interested in quantifying the impact of the new strategy on the entire supply chain due to tradeoffs from transitioning from the old strategy to the new strategy. Unlike SMEs that manufacture and warehouse multiple products with the same resources, the sponsoring company uses its manufacturing labor and warehouse space for one product. This simplified operational environment allowed the sponsoring company to measure the impact of the new strategy without any noise from other products.

1.2 Problem Statement

Although the sponsoring company had collected data to quantify the impact of the new inventory management strategy, it did not have KPIs identified for each operational department. Without agreed upon KPIs for each operational department, the sponsoring company had not decided how to quantify the impact of the new strategy.

This capstone had four main objectives. First, KPIs were created for the sponsoring company's procurement, demand planning, production, and order fulfillment operations before and after implementation. Second, statistical analysis was conducted to identify the sponsoring company's main drivers of revenue. Third, a Monte Carlo simulation analysis was designed using the main drivers identified in the statistical analysis to calculate the profitability impact that the new strategy had on the sponsoring company. Fourth, KPIs were calculated from before and after implementation with the input values of the Monte Carlo simulation analysis.

2. LITERATURE REVIEW

Developing a method to quantify the effects of modularization and postponement will inform the sponsoring company of the true impact of these inventory management practices and guide future supply chain strategy. This section reviews articles focused on modularization, postponement, regression analysis, and Monte Carlo simulations.

The articles informed the capstone team about modularization techniques and benefits, postponement techniques and benefits, an overview of regression analysis and its use in identifying significant variables, and an overview of Monte Carlo simulation and its use in quantifying supply chain cost savings.

2.1 Modularization

Modularization combines end-product flexibility with component standardization, providing opportunities to capitalize on economies of scale and aggregate forecasting benefits. (Star, 1965). The most visible benefit of modularization is the increased speed in designing product variation at low costs within the supply chain. (Sanchez & Collins, 2001)

Various successful applications in diverse industries highlight the benefits of modular product design. Table 1 below outlines practical applications of modular strategies in different operating environments.

Table 1

Modularization Applications

Year	2007	2005	2010
Author	Doran, Hill, Hwang, and Jacob	Lau and Yam	Hansen and San
Title	Supply Chain Modularization: Cases from the French Automotive Industry	Effects of Supplier and Customer Integration on Product Innovation and Performance in Hong Kong Electronics Industry	A Comprehensive View on Benefits from Product Modularization
Industry	French Automotive	Consumer Electronics	Electronics and Consumer Goods
Benefits	Increased flexibility, increased speed to market, and reduced cost	Pairing product modularization with coordinated supply chain design brings down inventory level, improves quality of conformance, reduces development lead time	Reduces product lifecycle costs, enhances speed, enhances flexibility, enhance learning
Downsides	Exposes risk opportunities such as increasing supplier complexity.	Requires increased and potentially expensive coordination	Benefit tradeoff exists between direct cost savings, capital binding, and lead times

It is clear various applications of modularization have been implemented in a wide variety of industries. Specific to our analysis, we are focusing on flexibility and speed related to modular packaging decisions. While we are focusing specifically on the CPG industry, the cases above show applicability and usefulness in many scenarios.

2.2 Postponement

Postponement strategies first appeared in the 1920s and are defined as adding value to a product by delaying customization until the end (Ernst and Kamrad 2000). Van Hoek, Commandeur, and Vos (1998) built upon the possible frameworks of postponement and outlined five main methods. The study found that when firms can add postponement techniques to their supply chains, they create an opportunity to apply mass customization to their products. Five postponement methods are identified in their research and are outlined below:

1. Create products and services that are customizable by customers
2. Modularize components to customize end products and services
3. Provide quick response throughout the value chain
4. Customize services around standard products or services
5. Provide point-of-delivery customization

Next, we will provide practical applications of postponement strategy and their placement within Van Hoek, Commandeur, and Vos' framework.

Jafari and Eslami (2022) discussed logistics flexibility that is created when postponement techniques are applied to a firm and analyzed how different logistics input drivers affected total firm performance. They utilized regression analysis to focus on maximizing quick response time throughout their supply chain created when practicing postponement techniques by studying 261 Swedish retailers. They highlight the collective push to implement postponement techniques that has led to Sweden’s retailers being ranked second in World Infrastructure Index.

Davila and Wouters (2006) used results from a tech hardware company that applied postponement and found statistically significant impacts on supply chain performance at both one and five percent levels leading to a decrease in variable costs and an increase in on-time performance. This research also points out the importance of redesigning products and processes to create highly customizable end-products and services.

Waller, Dabholkar, and Gentry (2000) found that postponement can add customer value, lower retail prices relative to competitors, minimize operational costs, and provide customers with precisely what they want. This study analyzed how these metrics positively impacted firm performance. For our research, a key project outcome is to create KPIs to measure the impact of the new inventory strategy for the sponsoring company and validate the effectiveness of a postponement strategy. Our analysis will focus on modularizing components to customize end-products and services, providing quick response throughout the value chain, and customizing services around standard products or services.

2.3 Regression Analysis and Monte Carlo Simulation

Understanding regression and stochastic simulations was essential to integrate the company strategy's critical factors into variables in the Monte Carlo simulation. First, we identified significant demand drivers with statistical analysis. Other researchers have utilized regression analysis to identify important factors, and their findings are summarized below:

- Tan (2006) connected the firm's performance to its supply chain management practices using multiple linear regression analysis. Specifically, through linear regression, the author was able to show significant statistical relationships between the use of different advanced shipping strategies and their impact on minimizing transit time.
- Hafni (2020) used multiple linear regression to see the effects of a variety of socioeconomic input factors such as age and income on the independent variable of financial satisfaction. Specifically, they found that input variables affected 43.7% of the total financial satisfaction by utilizing a regression model. Similar to this capstone

project, Hafni points out the difficulties when calculating the influence of variables with high interactions.

Based on these applications, we see regression analysis helps identify effects, interactions, and significant explanatory variables to describe a pattern. For this project, significant variables specified by the regression analysis will also be used to model better the Monte Carlo simulation and measure the impact of the new inventory strategy on company profitability.

We explored simulation models to capture the uncertainties associated with the randomness of processes and their effects on pre- and post-implementations of modularization and postponement. A Monte Carlo simulation was utilized to better capture the sponsoring company's operating environment. Monte Carlo simulation is a statistical simulation technique that randomly generates many scenarios and generates the probabilities of different business outcomes. Furthermore, Monte Carlo simulations have been frequently used to explain the risks and impacts of random variables in supply chain-related scenarios. Examples of Monte Carlo simulations used to model uncertainty in a supply chain settings are highlighted below:

- Ayanso, Diaby, and Nair (2006) developed a Monte Carlo model to analyze an inventory rationing policy for a direct-to-customer internet retailer. The Monte Carlo method is specifically used to understand the complexity drivers in the retailer's operating environment and different profit scenarios when conditions of uncertainty change.
- Baxandale (2004) identifies Monte Carlo simulations as one way to introduce uncertainty parameters to a decision-making process in SME environments. By repeating the

simulation many times, it is possible to glean insights into the sensitivity of the results to changes in the input variables.

- In a more recent study, Koroteev, Romanova, and Korovin (2022) applied Monte Carlo techniques to food production budgeting in the meat processing industry. Given a simple system with multiple interdependencies, they apply Monte Carlo methods to deliver a quantitative solution by using the theory of probability and the Weak Law of Large Numbers. A similar approach will be used in the project, including one million test runs for each scenario such that the mean gets closer to the average values obtained by the scenarios.

2.4 Gaps in Literature

We reviewed research that has explored the intersection of postponement and modularization, and the summaries below outline the existing literature, methodologies, and tools they employ:

- Ernst and Kamrad (2000) developed a framework for evaluating supply chains in both postponement and modularization. This study highlights the use of the total cost equation for particular supply chain structures to allow for an objective evaluation and encourages modularization and postponement decisions to be combined and that dual consideration augments operational advantages.
- Mikkola and Skjott-Larsen (2007) addressed three integration strategies: mass customization, postponement, and modularization. They propose a 'modularization characteristic curve' to define suitable products for modularization and postponement.

- Brun and Zorzini (2009) evaluated the crossover between postponement and modularization in Italian companies. They discussed the need for an integrated strategy to keep up with increasing customer pressure for customized products while still maintaining speed to market. They identified two main factors for judging the applicability of modularization and postponement strategies: 1) the degree of product customization and 2) the level of product complexity. On the other hand, they caution that over-application can lead to constraints related to lead times, contractual obligations, and technical or process-related failures.

While literature exists in the areas pertaining to the strategic alignment and implementation of postponement and modularization techniques, few studies quantify the results and benefits of the specific intersection between postponement and modularization. Few could capture detailed data on different operational factors due to the lack of noise in the supply chain from other products.

Our research aims to add to the empirical results for implementing modularization and postponement techniques, primarily through an SME lens. These quantitative and qualitative results will highlight the benefits and insights that can be used as an example for other SMEs that want to adopt similar inventory management techniques.

3. SPONSORING COMPANY OVERVIEW

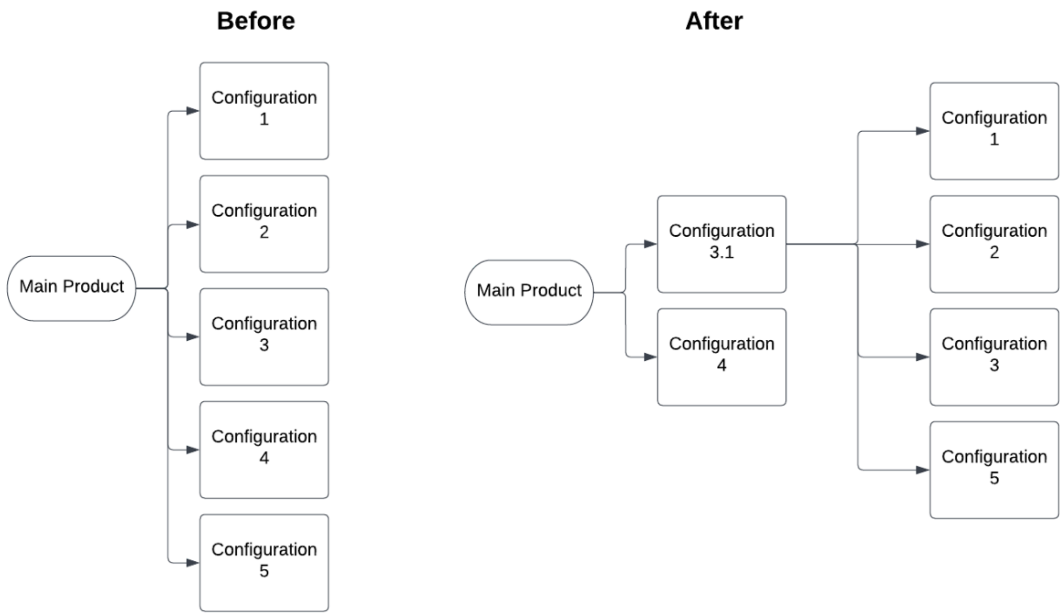
Based in the United States, the sponsoring company for this capstone project is a CPG company with less than 30 employees. The sponsoring company sells one main product directly to customers, primarily through e-commerce sales channels, and manufactures and distributes its main product in-house. The main product is currently sold and manufactured in five configurations that differ by product weight.

The sponsoring company experienced rapid growth in 2020, which exposed the following challenges: Procurement experienced supplier shortages and increased lead times for components due to the added complexities of multiple product configurations. Demand planning struggled to accurately forecast demand for each product configuration due to the uncertainty around forecasting five configurations with different demand patterns. Production teams experienced increased lead times due to increasing line changeovers due fluctuating demand for each configuration. Lastly, Order Fulfillment teams experienced shortages and excesses of product configurations due to fluctuations in customer demand at each warehouse location.

The sponsoring company needed to solve these issues quickly, so in September 2021 it implemented modularization and postponement techniques to its main product. The implemented changes on the product are outlined in Figure 1 below. There were two main changes to the product in the new strategy. First, instead of selling and manufacturing the main product in five configurations, the sponsoring company produced and sold its main product in two identical configurations. Second, instead of assembling and storing five unique configurations, the sponsoring company stored one configuration that could then be assembled into any other configuration after orders were placed by customers.

Figure 1

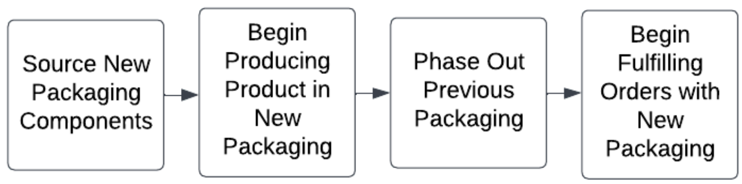
Product Configurations Before and After Implementation



After agreeing on the business benefits of implementing modularization and postponement techniques, a ramp-up phase, outlined in Figure 2 below, was implemented to ensure a smooth transition from the old strategy to the new strategy. Once the new packaging components were sourced, production teams began producing and transferring the main product in the new configuration to the sponsoring company's warehouses. All remaining inventory from the old strategy was then distributed to customers until inventory was depleted. The new strategy was then implemented end-to-end over a six-week period. The fifth week was used to train order fulfillment staff on how to configure the main product. This ramp-up phase was successful and implemented the new strategy without disrupting production, order fulfillment, and warehousing operations.

Figure 2

Ramp-up Phase



Since the ramp-up phase, the sponsoring company observed and recorded how the old and new strategies impacted procurement, demand planning, production, and order fulfillment operations, along with the benefits each operational group experienced with the new strategy. For further details on the processes impacted for each operational group, see Figures A1-A4 in Appendix 1. Procurement now sources four components instead of nine and has realized cost savings due to leveraging economies of scale. Demand planning has seen dramatic improvements in forecast variance now that all product configurations are aggregated into two configurations instead of five. Production no longer needs to perform production line changeovers because the two configurations in the new strategy are identical. Order Fulfillment has experienced fewer shortages and excessive product configurations but has also seen an increase in the time needed to fulfill orders. See Table 2 for a visualization of the benefits described above.

Table 2

Implementation Benefits

Before Implementation	After Implementation
5 Product Configurations	2 Product Configurations
Forecast 5 Products	Forecast 2 Products
9 Total Components	4 Total Components
3 Production Line Configurations	1 Production Line Configuration

Before the project, the sponsoring company collected operational data, but had not articulated its strategy or defined KPIs to benchmark the impacts of the new inventory strategy. Since the sponsoring company could only rely on the benefits it could easily observe, the company sought help to quantify the total impact of the new strategy.

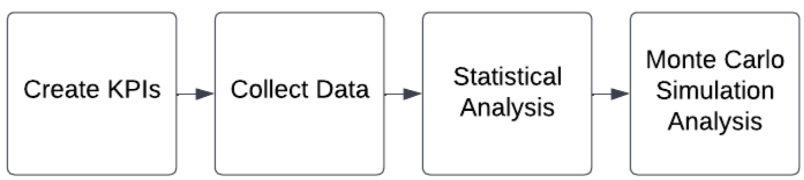
Quantifying cost and time savings of modularization and postponement was accomplished by developing KPIs for each operational group, measuring the KPIs before and after the implementation, and analyzing the inputs impacting the KPIs under several different conditions. KPIs were computed using data collected from each operational group and the collected data was reviewed by each group manager for accuracy. Although the sponsoring company had collected data from each operational group, it still was important to verify that data was accurate with each manager. Twenty-four months of operational data that covered before and after implementation was collected and used to quantify the impact. By measuring the results against specific benchmarks per group, the sponsoring company could better understand if the cost and time savings justified implementing the same inventory strategy in the future.

4. DATA AND METHODOLOGY

The methodology for the project consisted of understanding the company strategy, using the company's strategy to identify KPIs, collecting data, conducting a statistical analysis to identify the main drivers of revenue, and then using those main drivers as inputs in a Monte Carlo simulation analysis to calculate how profitability changes under different scenarios. This procedure allowed us to measure how well the new inventory strategy performed in different scenarios. An outline of each step in the methodology is outlined in Figure 3.

Figure 3

Methodology Outline



4.1 Understanding Overall Company Strategy

To best quantify the application of the two inventory management techniques discussed above—modularization and postponement—a deeper understanding of the sponsoring company's supply chain strategy in the context of their overall goals was necessary. Utilization of Perez-Franco, Singh, Caplice, and Sheffi's (2016) Conceptual System Assessment Reformulation (CSAR) strategy was used to help conceptualize the sponsoring company's supply chain strategy and design the survey given to the sponsoring company's leadership team.

For SMEs, supply chain strategy is often unspoken or may be implemented differently than designed. Aligning a firm's supply chain strategy to its corporate strategy is key to driving lasting results that benefit both the supply chain and the firm. The goal of developing and aligning a supply chain strategy with corporate strategy is to uncover areas of misalignment so a firm can begin to close the gap and hedge against operational failures. CSAR strategy is a step-by-step holistic approach to strategy formulation. The strategic insights gained from CSAR were used to establish potential scenarios that may be useful to be explored by the statistical analysis.

To operationalize CSAR and identify business priorities, a questionnaire was sent to each member of the ownership group of the company. For further details, see Table A1 in Appendix 2.

Each ownership group member responded to the questionnaire, and one owner was interviewed and shared the results of all three responses with the research team. The top operational goals identified and articulated by the ownership group as a result of the interview are in the list shown below.

- Increase Revenue
- Keep Headcount Low
- Minimize Complexity
- Maximize Asset Utilization

Once the top operational goals were articulated by the ownership group, the next step involved creating KPIs for each operational department that aligned with the top operational goals of the company.

4.2 KPI Development

A list of potential financial and supply chain metrics was created for each operational function, and the sponsoring company reviewed that list for approval. These metrics used in this capstone align with KPIs that were used in other studies referenced in the literature review. After meeting with the lead member of the ownership group, the KPIs that best define success for each operational department are listed below.

- Demand Planning
    - MAPE
- Procurement
    - Total Spend on Components
- Production
    - Production Efficiency
- Warehousing and Distribution
    - Warehouse Capacity
    - Order Fulfillment Efficiency
- Company's financial performance
    - Overall Profitability

The next step involved gathering data from before and after implementation to measure the impact on each KPI.

4.3 Data Collection

Several metrics required qualitative data, so data for those metrics were gathered through interviews with operational group managers. The research team received qualitative data for the following KPI metrics:

- Production efficiency through understanding units produced per hour before and after implementation
- Warehouse capacity by asking each warehouse manager to count the number of pallet spaces available before and after implementation in each warehouse
- Picking efficiency through understanding pick times for each product configuration before and after implementation
- Discussing with each operational group manager what processes changed before and after implementation to assist in measuring the overall change in company profitability

The interviews were also used to create process maps for each operational department. Each operational manager shared their department's processes before and after implementation. For further Details, see Figures A1-A4 in Appendix 1. The next step involved collecting all relevant business operations data from 2020 through 2021. We received quantitative data for the following KPIs:

- MAPE of monthly forecasts for each of the five product configurations
- Annual spend on components for each product configuration
- Monthly production labor costs
- Monthly production labor hours

- Warehousing and distribution labor costs
- Total costs to operate each distribution facility
- Weekly gross revenue for each product configuration
- Weekly units sold sales for each product configuration
- The total cost of producing each product configuration
- Profitability of each product configuration
- Weekly spend on advertising for each product configuration
- Promotion information for each product configuration

The data collected came from the sponsoring company's point of sale system, historical forecasts, actual sales reports, compensation reports, and warehouse expense reports. All data shared for each variable came from 24 months of information that began in January 2020 and ended in December 2021. Weekly sales per unit, promotion information, and profitability of each unit required data manipulation to convert the original data into units of measure that could be used to calculate KPI values.

4.4 Statistical Analysis

The next step involved analyzing the qualitative and quantitative data from the sponsoring company. The first goal was to understand revenue drivers for the sponsoring company. The second goal was to ensure that all significant variables were used in the simulation analysis. The variables used in the statistical analysis are in Table 3.

Table 3

Statistical Analysis Variables

Statistical Analysis Variables
Dependent Variable: Gross revenue - broken out on on a weekly level
Date - Sales aggregated on a weekly level
Orders - Number of orders placed per week
Promotion - Binary variable that described if there was an ongoing promotion in a given week
Discounts - Total amount of discounts applied to product purchases broken out on a weekly basis that helped describe the magnitude of ongoing promotions
Ad spend - Total dollar amount spent on advertising broken out on a weekly basis
Returns - Total dollar amount of returned items broken out on a weekly basis
Weekly unit movement of each of the 5 product presentations
Total active customers with scheduled recurring orders
Weekly gross revenue from scheduled recurring orders
Weekly gross revenue from non recurring orders

Descriptive statistics for each variable were then reviewed, and variables with large magnitudes of values were normalized. Normalizing these variables prevented the significant differences in magnitude between the variables from affecting the regression analysis results. Table 4 outlines the four variables that were normalized, and Equation 1 shows the equation used to calculate normalized values for input variables.

Table 4

Normalized Regression Analysis Variables

Normalized Regression Analysis Variables
Weekly unit movement of each of the 5 product configurations
Total active customers with scheduled recurring orders
Weekly gross revenue from scheduled recurring orders
Weekly gross revenue from non recurring orders

Equation 1

Data Normalization Formula

$$\zeta = \frac{f - \mu}{\sigma}$$

ζ = Normalized Value

f = Observed Value

μ = Mean

σ = Standard Deviation

Then, a correlation analysis was conducted to identify collinear variables. If variables with high multicollinearity (i.e., high correlation among several independent variables in a model) were included in the regression analysis that would occur in the next step, they would reduce the accuracy of the estimated coefficients while wrongly increasing the r-squared value of the regression analysis.

The next step consisted of running a multiple linear regression analysis with the input variables defined in Table 3. The team ran various scenarios with different input variables (e.g., all variables, exclude promotions, exclude date, exclude discounts, exclude ad spend, exclude returns, exclude product configurations movement, exclude recurring order variables, and exclude non-recurring order variables) to discover which combination described the most variation in gross revenue. When pairs of highly correlated variables were found to both be significant, at least one was excluded before calculating the results to prevent from falsely inflating the confidence level of the regression analysis.

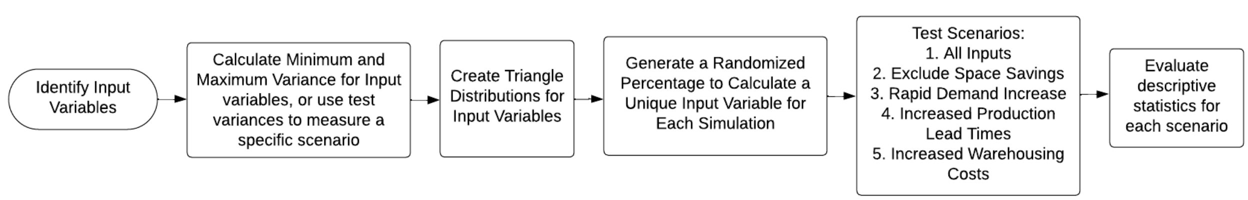
Statistically significant variables in the final regression analysis assisted the team in two ways. First, the regression analysis identified the key drivers of revenue which provide valuable management insight to the sponsoring company's leadership team. Second, the key drivers of revenue were then used as input variables in the Monte Carlo simulation analysis that measured the impact of the new inventory strategy on company profitability.

4.5 Monte Carlo Overview and Input Variables

The Monte Carlo simulation analysis was used in the project to create different scenarios and calculate the difference in overall profitability between the old inventory strategy and the new inventory strategy of the sponsoring company. An overview of how the analysis was conducted is outlined in Figure 4.

Figure 4

Monte Carlo Simulation Process Map



4.6 Monte Carlo Input Variables

The following variables in the list below were selected as inputs for the Monte Carlo simulation analysis. The variables were compiled using qualitative data, quantitative data, and results from the statistical analysis.

- Annual demand for each product configuration

- Annual demand variance for each product configuration
- Annual profit for each product configuration
- Annual variance in profit for each product configuration
- Annual production labor hours
- Hourly wage of production and warehousing labor
- Annual variance in cost of labor
- Time (in seconds) to pick and pack orders before and after implementation
- Variance in order fulfillment times
- Total Number of pallet spaces in distribution centers before and after implementation
- Cost per pallet space before and after implementation
- Annual gross revenue of each product configuration
- Production cost of labor
- Space savings from implementing new strategy
- Labor cost of picking and packing orders
- Annual profit

4.7 Monte Carlo Equations

The Monte Carlo analysis required calculations to create different test scenarios for each variable. The equations used to develop the Monte Carlo simulation analysis are outlined in Equation 2 through Equation 11 below. To test the robustness of the new inventory strategy, minimum and maximum variance values were calculated for each input variable with Equations 2 and 3, and those values were used to create minimum and maximum values that would be used in the triangle distribution formula in Equation 5. A triangle distribution is a continuous probability distribution with minimum, maximum, and mode values for a given variable. Once variance values were calculated for each input variable, Equation 4 calculated the “Ω” variable value by multiplying the “R” value, a random number between 1 and 0, by the "X" value, the input variable average, for each input variable. The “Ω” variable was then used as the input value in the triangle distribution formula in Equation 5, which created a randomized value for each input variable in the Monte Carlo simulation analysis.

Equation 2

Triangle Distribution Minimum (TDMin)

$$a = X - (X * s^2)$$

a = TDMin Value

X = Input Variable Average

s^2 = Annual Variance of Input Variable

Equation 3

Triangle Distribution Maximum (TDMax)

$$b = X + (X * s^2)$$

b = TDMaxValue

X = Input Variable Average

s2 = Annual Variance of Input Variable

Equation 4

Triangle Distribution Input Variable

$$\Omega = R * X$$

R = $0 \leq R \leq 1$

X = Input Variable Average

Ω = Randomized Variable Value

Equation 5

Triangle Distribution

$$F(\Omega|a,b,X) = \begin{cases} 0 & if\ \Omega < a \\ \frac{(\Omega-a)^2}{(b-a)(X-a)} & if\ a \leq \Omega \leq X \\ 1 - \frac{(b-\Omega)^2}{(b-a)(b-X)} & if\ X \leq \Omega \leq b \\ 0 & if\ \Omega > b \end{cases}$$

Ω = Randomized Variable Value from Equation 4

a = TDMin variable value from Equation 2

b = TDMax variable value from Equation 3

X = Input Variable Average

Equation 6

Gross Revenue

$$G = \sum_{i=1}^{n=5} \rho_i u_i$$

ρ_i = unitary profit of each product configuration *i*

u_i = number of product configuration *i* sold

Equation 7

Cost Per Pallet Space

$$Q = \frac{\frac{\sum_{i=1}^{n=5} k_i}{j_i}}{v}$$

k_i = monthly rent of each distribution center for configuration *i*

j_i = number of pallet spaces in each distribution center for configuration *i*

v = number of total distribution centers

Equation 8

Space Savings

$$H = z_i \frac{k_i}{j_i} - \Psi_i \frac{k_i}{j_i} * 12$$

k_i = Monthly rent of each distribution center from Equation 7

j_i = Number of pallet spaces for configuration *i* in each distribution center from Equation 7

z_i = Number of pallet spaces for configuration *i* in each distribution center after implementation

ψ_i = Number of pallet spaces for configuration *i* in each distribution center before implementation

Equation 9

Order Fulfillment Cost

$$L = \sum_{i=1}^{n=5} d_i y_i \alpha$$

d_i = Number of units picked for each product configuration *i*

y_i = Average picking time for each product configuration *i* before and after implementation

α = Cost of labor

Equation 10

Total Cost of Labor

$$C = \gamma + \phi$$

C = Total Labor Cost

γ = Production Labor Cost

ϕ = Pick Cost

Equation 11

Profit Formula

$$P = G - C + H$$

G = Gross Revenue Value from Equation 6

C = Total Labor Cost Equation Value from Equation 10

H = Space Savings Equation Value from Equation 8

4.8 Monte Carlo Simulation

Once feasible randomized values could be calculated for each of the input variables, a Monte Carlo simulation analysis was used to calculate overall company profitability for five scenarios based on the aggregation of one million randomized values.

The first scenario measured how the company performed with and without implementing modularization and postponement in the years 2020 and 2021 and utilized input variables that were reflective of the company's actual operating environment in 2020 and 2021. This scenario captured what occurred in 2020 and 2021 regarding demand, labor, and space savings costs. The four scenarios below measured profitability under four hypothetical circumstances.

The second scenario measured how the company performed with and without the implementation of modularization and postponement in the years 2020 and 2021 when excluding the space savings variable. The new strategy allowed pallets of product to be double stacked, but in the previous inventory strategy pallets were single stacked. If the sponsoring company transitions to a conventional warehouse with a pallet racking system instead of storing pallets on the floor, the space savings from the new strategy would not be applicable because pallet spaces would not increase in the new inventory strategy.

The third scenario measured how the company performed with and without the implementation of modularization and postponement in the years 2020 and 2021 with all input variables, but the maximum demand value was quadrupled to observe how the system performs under a demand shock. The sponsoring company was able to meet all of its demand in 2020 and

2021, but this simulation analysis was designed to capture how profitability would change if the company experienced an unprecedented increase in demand for each of its product configurations.

The fourth scenario measured how the company performed with and without the implementation of modularization and postponement in the years 2020 and 2021 with all input variables, but in this scenario production labor hours were quadrupled to simulate an event that would add time to the production process and increase the cost of production dramatically.

The fifth scenario measured how the company performed with and without the implementation of modularization and postponement in the years 2020 and 2021 with all input variables, but in this scenario the order fulfillment costs were quadrupled to simulate an event that would add time to fulfilling orders, which would increase the cost of order fulfillment labor dramatically.

Each scenario calculated four values: 2020 annual profit with the old strategy, 2020 annual profit with the new strategy, 2021 annual profit with the old strategy, and 2021 annual profit with the new strategy. Each value was calculated one million times for each scenario. One million test values were conducted to leverage the law of large numbers. The law of large numbers states that as the number of test runs increase, the closer the sample mean of the test runs approaches the population mean.

4.9 Monte Carlo Assumptions

The following assumptions were used in the Monte Carlo simulation analysis:

- The implementation of modularization and postponement does not affect consumer behavior because product prices and promotions did not change after implementation
- Product demand does not change before and after implementation
- Warehouse space savings should be included in calculating the overall profitability improvement because the sponsoring company realized actual space savings from the new strategy

The three assumptions were key in allowing the team to compare each of the two years of data with and without the new strategy to quantify the impact of the new strategy.

5. RESULTS AND ANALYSIS

The results and analysis chapter contains the statistical analysis results, Monte Carlo simulation results, and the new strategy's impact on KPI results.

5.1 Statistical Analysis Results

The correlation analysis identified seven pairs of variables that had correlation values above 0.7, and the seven pairs are outlined below. Variables that show higher values of correlation were explored meticulously before using them in the final regression analysis.

- Configuration 2 and Gross Revenue
- Weekly gross revenue from non-recurring orders and Gross Revenue
- Total active customers with scheduled recurring orders and Date
- Configuration 4 and Orders
- Weekly gross revenue from scheduled recurring orders and Orders

- Weekly gross revenue from non-recurring orders and Configuration 2
- Weekly gross revenue from scheduled recurring orders and Configuration 4

Non-significant variables with p-values larger than 0.05 were first removed, and then highly correlated pairs of variables remaining were identified. Next, the least significant variable in the correlated pair was removed, and the final regression was calculated. Date, Orders, Promotion, Configuration 1, Configuration 3, and Configuration 5 were the significant variables for this regression analysis. The final regression had an adjusted R-square value of 0.89. The resulting formula that describes the variance in gross revenue is Equation 12 below.

Equation 12

Regression Analysis Formula

$$Gross\ Revenue\ =\ 20.7\Theta_1 + 45.7\Theta_2 + 2726.6\Theta_3 + 5301.9\Theta_4 + 3698\Theta_5 + 3938.7\Theta_6 - 890373.96$$

Θ_1= Date

Θ_2= Orders

Θ_3= Promotion

Θ_4= Configuration 4

Θ_5= Configuration 1

Θ_6= Configuration 5

Identifying the final significant variables was important for two reasons. First, the regression analysis confirmed that the key drivers of gross revenue had been identified. Second, the final variables could then be used as input variables that calculated the revenue portion of the Monte Carlo simulation analysis.

5.2 Monte Carlo Results

Descriptive statistics were calculated for each of the five Monte Carlo simulation analysis scenarios. The percentage increase in profitability after implementation for each scenario is outlined in Table 5. Based on the results identified from the Monte Carlo simulations, the profit percentage increased in 2020 and 2021 for all five scenarios. The median, lower bound, and upper bound values in each table were used to compare the increase in profitability between the scenarios.

Each scenario helped the capstone team better understand how profitability changed based on the scenario. First, Scenario 1 calculated the actual savings the sponsoring company experienced from implementing the new inventory strategy. The average median and standard deviation values for Scenario 1 in 2020 and 2021 were 14.57% and 1.47%. Second, Scenario 2 provided evidence that space savings represented a large portion of the increase in profitability, but the implementation without space savings still increased profitability overall. The average median and standard deviation values for Scenario 2 in 2020 and 2021 were 3.16% and 1.43%. Third, Scenario 3 helped the team understand that a rapid increase in demand would not negatively affect profitability. The average median and standard deviation values for Scenario 3 in 2020 and 2021 were 9.14% and 2.32%. Fourth, Scenario 4 helped the team understand that increased lead times in production had a negative impact on profitability. The average median and standard deviation values for Scenario 4 in 2020 and 2021 were 2.47% and -3.33%. Fifth, Scenario 5 helped the team understand that an increase in order fulfillment lead time does not negatively affect profitability. The average median and standard deviation values for Scenario 5 in 2020 and 2021 were 14.63% and 3.12%. Median and standard deviation values differed by scenario because the input variables affected profitability differently. The goal of running these five scenarios was to understand the amount of weight the tested input variables had on overall profitability.

Table 5

Monte Carlo Simulation Results

Scenario 1: Monte Carlo With All Inputs

Profitability Results	**2020 Annual Profit Percentage Increase After Implementation**	**2021 Annual Profit Percentage Increase After Implementation**
Mean	15.49%	13.60%
St Dev	1.52%	1.42%
Min	20.14%	16.76%
Max	10.54%	10.23%
Median	**15.52%**	**13.62%**
Lower Bound	**19.97%**	**17.63%**
Upper Bound	**12.79%**	**11.20%**

Scenario 2: Monte Carlo Excluding Space Savings

Profitability Results	**2020 Annual Profit Percentage Increase After Implementation**	**2021 Annual Profit Percentage Increase After Implementation**
Mean	3.06%	3.23%
St Dev	1.30%	1.55%
Min	6.10%	9.13%
Max	2.87%	4.42%
Median	**3.08%**	**3.23%**
Lower Bound	**3.65%**	**3.78%**
Upper Bound	**2.73%**	**2.90%**

Scenario 3: Monte Carlo Rapid Demand Increase

Profitability Results	2020 Annual Profit Percentage Increase After Implementation	2021 Annual Profit Percentage Increase After Implementation
Mean	9.55%	9.43%
St Dev	4.10%	0.54%
Min	20.07%	8.73%
Max	10.66%	-1.02%
Median	**9.48%**	**8.80%**
Lower Bound	**19.64%**	**14.22%**
Upper Bound	**7.35%**	**6.46%**

Scenario 4: Monte Carlo Increased Production Lead Times

Profitability Results	2020 Annual Profit Percentage Increase After Implementation	2021 Annual Profit Percentage Increase After Implementation
Mean	2.90%	3.36%
St Dev	-11.53%	4.87%
Min	15.52%	3.59%
Max	1.97%	1.04%
Median	**0.76%**	**4.18%**
Lower Bound	**5.26%**	**3.93%**
Upper Bound	**-1.84%**	**4.33%**

Scenario 5: Monte Carlo Increased Warehouse Costs

Profitability Results	2020 Annual Profit Percentage Increase After Implementation	2021 Annual Profit Percentage Increase After Implementation
Mean	15.55%	13.24%
St Dev	2.16%	4.08%
Min	15.96%	9.00%
Max	8.39%	8.25%
Median	**16.03%**	**13.22%**
Lower Bound	**20.53%**	**15.93%**
Upper Bound	**13.30%**	**11.51%**

5.3 KPI Results

KPIs before and after implementation were calculated using data collected from the sponsoring company and with the results of the Monte Carlo simulation analysis. The total spend, production efficiency, order fulfillment efficiency, and warehouse capacity KPIs were calculated based on the before and after implementation annual values calculated when setting up the Monte Carlo input variables. The profitability KPI was calculated based on the average of the median values from Scenario 1 of the Monte Carlo simulation analysis. The MAPE KPI was calculated based on comparing the average forecast MAPE values from before and after implementation for the main product. Although calculating the change in MAPE for the sponsoring company was outside the scope of our statistical analysis and simulation analysis, this supplementary information was insightful for the sponsoring company.

The percentage improvement for each KPI is outlined in Table 6. All KPIs except for Order Fulfillment Efficiency improved. However, even though Order Fulfillment Efficiency decreased by 65% between the old and new inventory strategy, Scenario 5 of the Monte Carlo simulation provided evidence that the 65% decrease in efficiency did not negatively impact profitability for the sponsoring company. The KPI results represented quantitative evidence that calculated the impact the new inventory strategy had on the sponsoring company.

Table 6

KPI Results

KPI Metrics	Percentage Improvement After Implementation
Profitability	14.57%
Production Efficiency	-50%
Warehouse Capacity	52.6%
Order Fulfillment Efficiency	65%
Total Spend	-2.41%
MAPE	-42.20%

Three relationships were discovered between KPIs when comparing KPI results to the simulation analysis results. First, our results show that production efficiency and order fulfillment efficiency are negatively correlated. The dramatic increase in efficiency in production from the new strategy resulted in a decrease in efficiency for order fulfillment. Second, warehouse capacity and profitability were found to be positively correlated due to the 11.42% decrease in overall profitability between Scenarios 1 and 2 of the simulation analysis. Third, profitability, MAPE, and total spend, are also positively correlated. Implementing the new inventory strategy significantly reduced the MAPE of the main product due to aggregating demand and total spend decreased due to better economies of scale. Data for each KPI will be collected by each operational group going forward so that the sponsoring company can monitor how KPIs change once more post-implementation data is available.

6. DISCUSSION AND RECOMMENDATIONS

The discussion section will elaborate on the quantitative results from the statistical analysis, Monte Carlo simulation analysis, and KPI results.

6.1 Statistical Analysis Insights

Four insights were shared with the sponsoring company as a result of the statistical analysis. First, the six significant variables combined to explain 89% of variance in revenue based on the final regression analysis, which means that understanding how each variable impacts revenue is important to increasing revenue going forward. Second, there is opportunity for the sponsoring company to continue researching the interconnectedness of the six significant variables. For example, the sponsoring company should explore how ‘Date’ affects revenue because it is a main driver of revenue. Understanding annual seasonality, monthly seasonality, and weekly seasonality could help the sponsoring company understand seasonal fluctuations and capture more customers in the future. Third, Promotions should be reviewed by the sponsoring company due to its significant impact on revenue. Although promotions significantly increase revenue, the sponsoring company should review its past and upcoming promotions to understand how each promotion affected company profitability. Fourth, Configurations 1, 3, and 5 should be closely monitored by the sponsoring company. Configuration 1 creates the most overall revenue and is most often ordered by repeat customers. Configurations 3 and 5 generate the most revenue for new and infrequent customers. We recommend that the sponsoring company should continue to advertise Configurations 3 and 5 to new customers and advertise Configuration 1 to infrequent customers who purchase Configurations 3 and 5 to increase revenue.

The statistical regression analysis results provided two main benefits relevant to our research. First, identifying the significant factors that drive revenue for the sponsoring company can be used by the leadership team to make informed business decisions about how to increase revenue in the future. By identifying which input factors are most significant in driving revenue, the leadership teams can make better informed operating decisions. Second, these significant factors served as the inputs for the Monte Carlo simulation conducted later in the study. Our goal was to find the most relevant factors to driving revenue to create a simulation that best represented the sponsoring company's operating environment. Since the Monte Carlo simulation analysis was measuring profitability, all significant factors that drive revenue needed to be included in the simulation analysis.

6.2 Monte Carlo Simulation Insights

The results of Scenario 1 in Table 5 in section 5.2 increased profitability by 14.57%. Scenario 1 represents the total increased profitability realized by the sponsoring company from implementing its new inventory strategy. The other four hypothetical scenarios explored how profitability was impacted when different variables changed. The profitability in Scenario 2 was 3.15%, which showed that the majority of the 14.57% increase in profitability from Scenario 1 was a direct result of space savings. Understanding the significance of space savings is valuable for the sponsoring company as its impact on profitability can change depending on the warehouse configuration.

Scenario 3 found that rapid increases in demand increased profitability by 9.14%. Compared to Scenario 2, demand increases did not reduce profitability as much as excluding space savings. Scenario 4 found that production lead times increased profitability by 2.47%. The increase in production lead times resulted in the lowest increase in profitability for the sponsoring company. This discovery shows that reducing production lead times most considerably impacts profitability. Scenario 5 found that profitability increased by 14.63% when order fulfillment costs increased. These results proved that increases in order fulfillment costs had a minimal effect on profitability when compared to the results in Scenario 1.

Another key takeaway from our simulation analysis was understanding the magnitude of change in profitability when increasing or decreasing input variables. The largest delta existed between the impact of increasing two different warehousing functional lead times-- production lead time versus order fulfillment lead time. The simulation analysis highlighted the importance of reducing production lead times as it dramatically influenced the output variable, profitability. On the other hand, order fulfillment lead time fluctuations were not as impactful. This means that the company should focus on optimizing production processes and should tolerate fluctuations in order fulfillment lead time as long as they are still meeting customer expectations.

Scalability was not captured in the quantitative results of the Monte Carlo simulation, but the additional capacity to scale created by the new inventory management strategy cannot be overlooked. The sponsoring company is now in a much better position to scale after implementing the new strategy due to reduced production lead times and increased warehouse space. Since applying modularization and postponement techniques, the sponsoring company has unlocked additional production and warehousing capacity to add new products to its portfolio without increasing headcount, production capacity, or warehouse capacity.

6.3 KPI Impact Insights

MAPE, Total Spend, Production Efficiency, Production Labor Costs, and Warehouse Capacity improved after implementation while order fulfillment costs increased. However, the results of Scenario 5 in the simulation proved that increasing order fulfillment costs did not significantly impact profitability and represented a favorable tradeoff in each scenario. These results provided evidence that the savings in production and warehousing outweighed the increase in order fulfillment costs. Below are steps the sponsoring company can take to continue to leverage the efficiencies discover by the statistical and simulation analysis:

- Continue to trust the aggregate forecast as growth and revenue increase and resist the urge to manually forecast or overbuild safety stock.

- The implementation of modularization most dramatically affected the production process as efficiency improved 50%. The simulation analysis also revealed this area's importance to profitability, so this area should be a focus for efficiency and improvement activities.
- While savings were captured by leveraging economies of scale via the need to purchase a higher quantity of a specific type of packaging, it also increased the inherent risk to a supply disruption for the singular packaging. We recommend the sponsoring company have back-up suppliers in case of a disruption with the primary packaging provider.

7. CONCLUSION

In our research, we quantified the true impact of implementing a modularization and postponement strategy in a SME environment. While the sponsoring company observed some positive impact of the implementation of these techniques, we used statistical and simulation methods to specifically outline how different input variables behave under different probability-driven scenarios iterated thousands of times. With this analysis, we were able to show the actual impact of implementing these strategies and how they affect the sponsoring company's different supply chain departments and impact on overall performance metrics.

Other small businesses that produce, warehouse, and fulfill orders for their products could also benefit from the modularization and postponement strategy implemented by the sponsoring company. The following four results from our study showcase why implementing a similar strategy is beneficial: an increase in profitability, a reduction in production lead times, a reduction in forecast variance, and an increase in a company's ability to scale.

7.1 Limitations

Some limitations exist in our analysis related to available data and reliance on qualitative data to generate quantitative input variables. First, this capstone measured the impact of implementing modularization and postponement based on two years of company data. While results from this specific time sample size are positive, these results highly depend on the company's data. Second, we work with fragmented and imperfect data; then, our results should be taken with precaution. Third, the Monte Carlo models operated under the assumption that the demand and customer preference would not increase or decrease given changes to physical product packaging, considering the product configurations of the sponsor company. Under this assumption, before and after simulations were run on historical data to compare KPIs and profitability metrics versus attempting to forecast and quantify future demand.

7.2 Recommendations

As the sponsoring company continues to scale and add new products, we recommend applying modularization and postponement techniques to continue adding flexibility and increasing efficiency in the future. To best measure the effects of the new strategy, we recommend updating and simulating the model under the following circumstances: a material change in costs or demand, new product lines are added, and at recurring time intervals to capture accurate input values for the simulation. The sponsoring company should continue to monitor KPIs for each operational group as the cost of labor and other variables change.

7.3 Future Research

Our research highlights the positive impact of modularization and postponement strategies for SMEs. Given the operational constraints for the sponsoring company, limits on specific input variables were constrained to portray the sponsoring company's business environment accurately. One opportunity for future research includes modeling the impact of adding warehousing and manufacturing capacity when demand exceeds current network capacity. Quantifying this impact was not in scope for this capstone project. Still, additional research would benefit SMEs that are currently scaling their warehousing and manufacturing operations but also applying inventory management strategies simultaneously.

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APPENDICES

Appendix 1: Operational Processes by Department Before and After Implementation

Figure A1

Demand Planning Before and After Implementation

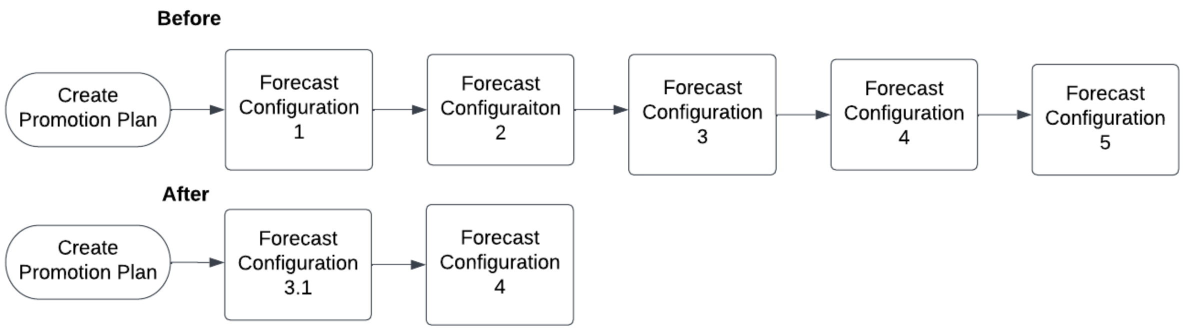


Figure A2

Procurement Before and After Implementation

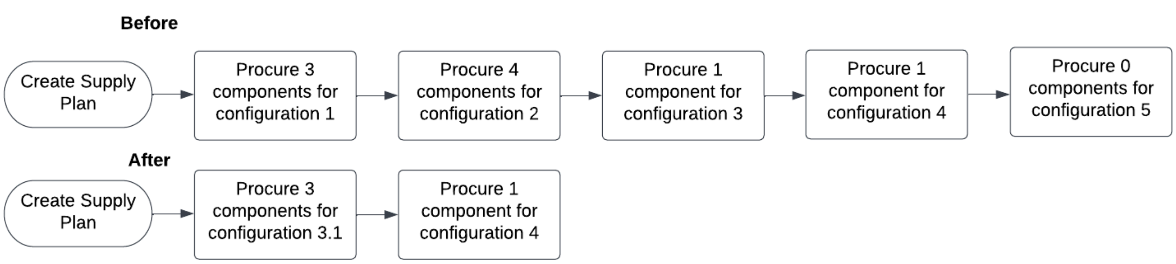


Figure A3

Production Before and After Implementation

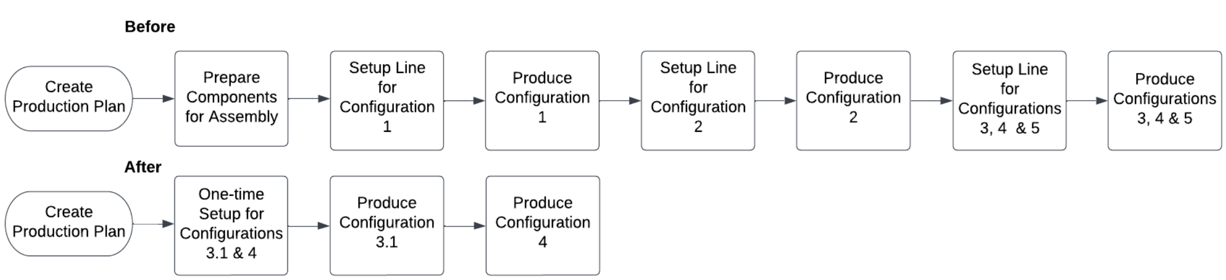
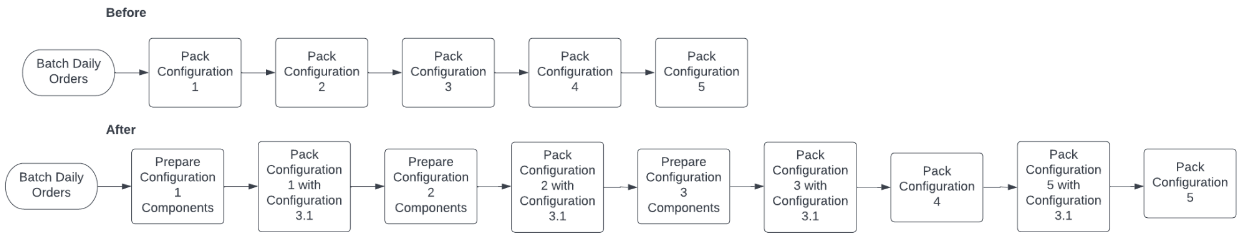


Figure A4

Warehousing and Order Fulfillment Before and After Implementation



Appendix 2: Strategy Questionnaire

Table A5

Strategy Questionnaire

Strategy Questionnaire
1. How do you expect demand to change in the next year, and over the next 5 years?
2. How do you plan to forecast the anticipated changes in demand in the next year, and over the next 5 years? Do you prefer forecasting with the new presentation structure?
3. How do you logistically plan to keep pace with changes in demand?
4. If lead times increase, what is your strategy for ordering components?
5. Do you plan to keep production in-house, or do you think you will outsource production?
6. How do you plan to handle transportation issues should it be difficult to get trucks to deliver finished goods to each distribution center?
7. How do you think the company will perform financially over the next five years with the new presentation structure?
8. How do you think the company will perform financially over the next five years with the new presentation structure?
9. Do you see any barriers that would hinder future operations goals over the next five years while using the new presentation structure?